



Another EMC resource  
from EMC Standards

Three day course for cost-effective EMC design for  
electronic products in 2023

*Helping you solve your EMC problems*

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# **Practical Electronic Design Techniques for Cost-Effective SI, PI and EMC, in 2023** (2 days)

— *plus* —

## **Essential PCB Design & Layout Techniques for SI, PI, & EMC, in 2023** (1 day)

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### A Three-day Training Course

by

Keith Armstrong  
Cherry Clough Consultants Ltd, U.K.

Keith was the first recipient of the IEEE EMC Society's new  
"Excellence in Continuing EMC Education Award", in 2018

Presented for "Continuous education in EMC, signal integrity and power integrity  
from a practically based point of view"

#### **Synopsis**

Training for electronic, mechanical and PCB design engineers, and their managers, in the use of good SI, PI and EMC design and manufacturing practices for modern products and equipment.

This course *does not cover* low-frequency emissions and power quality issues for AC-DC power converters, because many manufacturers purchase them as discrete units already compliant with the relevant standards. Other course modules are available to customise this course.

This is the same as our 4-day course, but with the day on Advanced PCB design topics removed.

Many more different course modules are available to customise this course.

A 5-day version is available that adds more SI, PI and EMC topics and generally provides everything that electronic designers need to know, including low-frequency power converter issues.

#### **Objective**

The aim of the course is to help companies quickly improve their commercial and financial performance by using design techniques that have been proven in real-life for many years to:

- Bring advanced products to market more quickly
- Reduce unit manufacturing costs

- Reduce warranty costs and costs of ownership by improving reliability
- Easily comply with legal EMC requirements
- Reduce financial risks and improve Return On Investment

This course is highly recommended for those involved in any aspect of the design or testing of electrical/electronic products.

It is based upon the EMC course module that Keith taught to post-graduate students as part of the IET-accredited Sensors and Electronic Instrumentation M.Sc. course at the University of Manchester (formerly UMIST, University of Manchester Institute of Science and Technology), UK.

## Who Should Attend

All electronic designers and their managers, in all industry areas, including:

Automotive (vehicles and infrastructures)	Medical & healthcare
Consumer electronics	Household (domestic) appliances
Information Technology (IT)	Industrial instrumentation or control
Process control	Entertainment, inc. TV and radio broadcasting
Railway (vehicles and infrastructures)	Telecommunications
Marine (vehicles and infrastructures)	Radiocommunications
Aerospace (vehicles and infrastructures)	Military, security, and defence
Power generation and distribution	Datacommunications

## Prerequisites

Familiarity with circuit (hardware) design, PCBs/PWBs and electronic and mechanical assembly and interconnection techniques.

Plain English is used, with a small amount of very easy mathematics.

## Course Methodology

This course is presented classroom style using a PowerPoint slideshow containing practical illustrations of the techniques to aid understanding.

Case studies that are relevant to the trainees will be included verbally.

Each attendee will be provided with a colour-PDF copy of the PowerPoint slides used during the training, printed at 2 slides per page (for viewing/annotating on a personal device), plus a version with 6 slides per page (for colour-printing, if required). The spaces around the slides usually suffice for taking extra notes.

Copies of textbooks (see page 7) can be provided at extra cost.

## Course Duration

Three (3) full days, each 9:00am – 5:00pm (for example) Other timings could be used.

This is a very intensive course with a very large amount of practical detail.

If presented as an in-house course it can be very usefully combined with individual consultancy for each engineer or manager, to help him or her apply the material to his or her current projects.

In countries where English is not the first language, a longer duration may be preferred.

## Venue and Date

To be decided. The course could be provided as a public course, or as an in-house course, either 'in person' (face-to-face), or on-line with a maximum of 1,000 attendees.

As an in-house course, it has the added value of allowing confidential discussions on how best to apply the material to particular projects or products.

## COURSE OUTLINE

### DAY 1

#### A. EMC and Interconnections 2hrs

All electronic, cabling, and mechanical / packaging designers should attend, at least

- 1 'Accidental antenna' behaviour of all conductors
- 2 Using fibre-optics, and other alternatives to conductors
- 3 The "RF Reference"
- 4 Cable classification and 'EM Zoning' (segregation)
- 5 Good practices for shielded and unshielded interconnections: DM & CM paths
- 6 Shielding techniques for cables
- 7 Terminating cable shields
- 8 Interconnecting shielded enclosures
- 9 Dealing with 'ground loops'
- 10 Transmission-line interconnections
- 11 Some useful references

#### B. Filtering for EMC 2hrs

All electronic, cabling, and mechanical / packaging designers should attend, at least

- 1 Filtering is not 'black magic', 'EM Zoning'
- 2 How filters work
- 3 The advantages of soft ferrites
- 4 CM filtering
- 5 Specifying filters
- 6 Real-life problems with resonances, inductors, and capacitors
- 7 Earth leakage currents and safety
- 8 Filter construction, mounting, and cabling
- 9 The synergy of filtering and shielding
- 10 Some useful references

#### C. Shielding 2hrs

All electronic, and mechanical / packaging designers should attend, at least

1. Economic issues for shielding
2. Shielding with metal plates (image planes)
3. How shielded enclosures work
4. DC and low frequency shielding
5. The problems caused by apertures
6. The problems caused by box resonances
7. The problems caused by conductor penetrations
8. Shields in the near field of a source
9. RF-bonding with multiple metal bonds or conductive gaskets
10. Waveguides-below-cutoff

11. Shielding of displays
12. Shielding of ventilation
13. Shielding of plastic enclosures
14. Preventing corrosion at shielding joints
15. D-I-Y testing SE before hardware or software is ready
16. Shielding with 'clamshell' enclosures
17. Some free SE calculators and useful references

## DAY 2

### D. Circuit design for EMC

2hrs

All electronic designers should attend, at least

#### Digital circuits

- 1 Rise/fall times and emissions spectra
- 2 Numerous digital circuit design techniques
- 3 Watchdogs and brownout monitors
- 4 Data scrambling and spread-spectrum clocking
- 5 Design of firmware and software

#### Analogue circuits

- 5 Linearity, bandwidth and stability of feedback circuits
- 6 Numerous analogue circuit design techniques, using hysteresis in comparators

#### Switching power converters

- 7 Cleaning up switching waveforms; using 'spread-spectrum'
- 8 Snubbers; and reducing output ripple
- 9 Heatsinks
- 10 Use SiC Schottky or soft-switching rectifiers, SiC or GaN switching devices
- 11 The isolating transformer's interwinding capacitance
- 12 Don't over-use galvanic isolation!

#### Communications circuits

- 13 Better alternatives to copper cabling
- 14 How to use copper cabling
- 15 Common-mode noise reduction techniques
- 16 Optoisolators and optocouplers
- 17 Gigabit laser diodes
- 18 Terminating transmission line
- 19 Some useful references

### E. Component selection for EMC

1hr

All electronic designers should attend, at least

- 1 Active devices
- 2 Passive components
- 3 Problems with second sources, counterfeits, and controlling purchasing
- 4 Some useful references

## **F. Suppressing electrostatic discharge (ESD)**

1hr

All electronic, PCB, and mechanical / packaging designers should attend, at least

- 1 ESD threats
- 2 Insulation techniques
- 3 Shielding techniques
- 4 Suppressing signal, data and power connector pins and conductors
- 5 PCB layout for ESD suppressors
- 6 Earth lift problems in systems
- 7 Protecting control, data and signals from errors
- 8 Some useful references, including “software techniques for ESD suppression”

## **G. Suppressing surges/transients on AC & DC power supplies, signals & data**

(A version of this is available specifically for military vehicles)

2hrs

All electronic designers should attend, at least

- 1 What transients are, and how they cause damage
- 2 Galvanic isolation for transient suppression
- 3 Transient suppression using filters
- 4 Types of surge protection component (SPC)
- 5 Rating SPCs
- 6 Protecting and maintaining SPCs
- 7 Lead inductance and “let-through” voltage
- 8 Avoiding the effects of SPC capacitance on signals
- 9 Types of surge protection devices (SPDs)
- 10 Electronic transient protection for DC power supplies
- 11 “Earth/ground lift” problems in systems
- 12 Data needs error correction
- 13 Dealing with long-duration overvoltages
- 14 Some useful references

## **DAY 3**

## **H. Essential design/layout techniques for SI, PI and EMC for all PCBs in 2023**

All electronic, PCB, and mechanical / packaging designers should attend, at least

Full day

- 1 The scope of these layout techniques
- 2 Saving time and money
- 3 EM Zoning (segregation)
- 4 Interface analysis, filtering, and suppression
- 5 0V(GND) and power (PWR) planes
- 6 PCB-chassis bonding
- 7 Power supply decoupling
- 8 Switching power converter layout (AC-DC, DC-DC, AC-AC)
- 9 Matched transmission line techniques
- 10 Layer stacking and trace routing
- 11 Devices with BGA packages and/or multiple DC rails
- 12 Some useful references, sources, and webinars

A more detailed course contents list is available upon request.

*Note 1: Modules recommended as additions or replacements for the above standard course:*

- **Getting Started with EM Engineering, List of Resources** 0.5 hr
- **Cost-effective uses for near-field probing, and RF current monitoring in every project stage, for emissions, immunity, and more!** 2 hrs
- **Introduction to EMC and EMI** 2 hrs
- **The Physical Basis of EMI and EMC (Maxwell's without maths!)** Half-day
- **EMC Awareness – the Myths and the Realities** 2 hrs
- **EMC design of heatsinks** 1.5hrs
- **Analogue design techniques for SNR and EMI immunity** Half-day
- **Switch-mode power conversion** Full-day
- **Good EMC practices for cabinets, systems and installations** 1.5 days

Many more modules are available – if you don't see what you want, please ask!

## Course Instructor

### Academic Qualifications

BSc (Elec.Eng), Upper 2<sup>nd</sup> Class with Honours, Imperial College of Science & Technology, London, UK, 1972

### Professional Qualifications

Fellow IET (Institution of Engineering and Technology, formerly the Institution of Electrical Engineers, IEE), London, UK (Member since 1977) 2010  
 Senior Member IEEE (Institute of Electrical and Electronic Engineers Inc.) USA, member of its EMC, Product Safety Engineering Societies since 1998 2010  
 Associate of the City and Guilds Institute, London, UK 1972  
 UK Chartered Engineer, Engineering Council, London, UK 1978  
 Group 1 European Engineer (Eurlng), FEANI, Paris, France 1988  
 Presented with the IEEE EMC Society's new "Excellence in Continuing EMC Education Award" 2018



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### Professional Activities

Chair of IEE/IET's Working Group on EMC and Functional Safety 1997-date  
 Chair of IEEE EMC Soc. Special Committee on Risk Management of EMC 2012-2016  
 UK expert appointed (by invitation) to IEC maintenance team MT23 for IEC 60601-1-2 (Medical Equipment/Systems EMC) 2006-date  
 UK expert appointed (by invitation) to IEC maintenance team MT15 for IEC 61000-1-2 (EMC & Functional Safety) 2003-date  
 UK expert appointed to IEC 61000-6-7 (EMC & Functional Safety, Generic) 2010-date  
 Member EMC Industries Association (EMCIA) 2003-date  
 Member EMC Test Labs Association (EMCTLA) and its Working Group B 2001-date  
 Editorial board member, Inside Functional Safety magazine 2010-date  
 Editorial Advisory board member, Interference Technology magazine 2007-date  
 Editorial Advisory board member, In Compliance magazine 2005-date  
 EMCIA representative to BSI GEL 210/12 EMC committee 2009-date  
 President of the EMC Industries Association (EMCIA) 2008-2010  
 Vice-President of the EMC Industries Association (EMCIA) 2010-2012  
 Chair of IEE's EMC Professional Group (E2) 1997-1999



### RECENT RELEVANT EXPERIENCE (1990-PRESENT)

Started Cherry Clough Consultants in 1990, Director of the Limited Company since 2010.  
Started EMgineering Ltd (owns [www.emcstandards.co.uk](http://www.emcstandards.co.uk)) and appointed Director, October 2017.

External lecturer, Sensors and Electronic Instrumentation MSc course, University of Manchester, teaching an IET-accredited module on practical EMC design techniques, 2002/3 – 2007/8.

The services that Keith provides for Cherry Clough Consultants include:

- Product, system, and installation EMC and safety good practices for reliability and cost-effective regulatory compliance.
- Assessment of electromagnetic environments
- Control plans, test plans, etc., for effective management of EMC and safety in projects of all sizes. De-risking projects as regards EMI and EMC issues.
- Company procedures for EMC and safety, for financial benefits and regulatory compliance
- Production / QA procedures for maintaining regulatory compliance in volume manufacture and custom engineering
- Testing and remedial work to meet EMC and safety standards
- Creation of EMC Directive Technical Construction Files and other compliance documentation
- Assessment of EMC Directive Technical Construction Files for EMC Competent / Notified Bodies
- Education and training for designers and managers on cost-effective EMC and Safety techniques; and on "Functional Safety Risk Management of EMI"
- Education and training for executives in EU compliance; liability; financial benefits of using good EMC techniques; and related marketing issues

The above services have been applied in the following areas (not a complete listing):

### **Systems and installations:**

Machinery and manufacturing/process plant of all sizes

Robotics

Air traffic control towers

Computer and telecommunication rooms

Administration centres

Financial dealer rooms

Professional audio systems and installations (e.g. theatres, opera houses, recording studios)

Steel rolling mills

Hospitals

Hotels

Chemical and pharmaceutical processing plant

Nuclear processing plant

Bottling and canning lines

Road tunnel lighting schemes

Broadband-Over-Power-Line (BPL) systems

Railway and tram systems

Mobile X-ray systems for shipping containers

Synchrotrons (inc. the Diamond Light Source, Harwell, Oxfordshire, [www.diamond.ac.uk](http://www.diamond.ac.uk))

Fusion reactors, Tokamaks, (e.g. the ITER project in southern France, [www.iter.org/](http://www.iter.org/))

### **Products and items of equipment:**

Industrial instrumentation, control, and machinery of all sizes

Variable speed AC and DC motor drives from very small to 10MW

Automotive engine control units (ECUs) and other electronic subassemblies (ESAs)

Information technology equipment (ITE) e.g. computers, servers, RAID arrays

Personal Digital Assistants (PDAs) and other hand-held wireless-enabled computing devices

Marine equipment

Computers

Photocopiers

Digital Signal Processing

Datacommunications devices

Professional audio consoles and other equipment

Professional video projectors

Lighting

Telephones and telecommunications

Consumer electronics (TV, Hi-Fi, etc.)

Radiocommunications, cellphones and pagers

Lifts (elevators)

Domestic (household) appliances

Gambling machines

Gas boilers

Electricity meters

Electrical power generators (small scale)

Building electrical services equipment

Subsea oil and gas production equipment

Robots

Solar power converters

Military avionics

Medical equipment (various)

Microscope manipulators

Coin mechanisms

Security equipment

Mains-borne communications



Induction heating  
Digital microwave radio

Laser welding  
Variable-speed winch for a military submarine

### **PREVIOUS PROFESSIONAL EXPERIENCE (1982-1990)**

Keith was mostly involved with the design and development of state-of-the-art capital equipment during the period 1968 to 1990. He has wide experience in electronic product design and project management in the UK, South Africa and France, after finishing graduate apprenticeship with Thorn Automation in 1973.

Technically, he started in analogue design in 1968; adding digital control of analogue circuits in 1978, and A/D and D/A conversion in 1980. Project and departmental management experience was gained from 1983 onwards, including teams of more than 20 engineers and scientists (this was for the Microwave division of Marconi Instruments Ltd, Stevenage, UK, 1983-1988).

### **BOOKS, PUBLICATIONS and PAPERS**

#### ***EMC Design Techniques for electronic engineers***

Nutwood UK November 2010, ISBN: 978-0-9555118-4-4, full colour graphics throughout.

Order from [www.emcstandards.co.uk/books4](http://www.emcstandards.co.uk/books4). Covers all electronic applications, with a very practical approach to good design practices that will save time and cost, reduce time-to-market, and reduce warranty costs and financial risks.

(Chapter 2 of this book is the complete text of "The Physical Basis of EMC" (below), so don't buy both!)

#### ***The Physical Basis of EMC***

Nutwood UK October 2010, ISBN: 978-0-9555118-3-7, full colour graphics throughout.

Order from [www.emcstandards.co.uk/books4](http://www.emcstandards.co.uk/books4). Provides an understanding of electromagnetic phenomena, in a way that can be easily understood by practising electronic engineers.

(Chapter 2 in "EMC Design Techniques for electronic engineers" is the same text, so don't buy both!)

#### ***EMC for Printed Circuit Boards – Basic and Advanced Design and Layout Techniques***

Nutwood UK December 2010, ISBN 978-0-9555118-5-1, full colour graphics throughout. (2nd Edition, identical to 1st Edition except for format.) From [www.emcstandards.co.uk/books4](http://www.emcstandards.co.uk/books4)

Practical good-practice EMC design techniques for printed circuit board (PCB) design and layout, for designers of electronic circuits and PCB designers themselves. All application areas are covered, from household appliances, commercial and industrial equipment, through automotive to aerospace and military. This book is used by some University courses.

#### ***The First 500 'Banana Skins'***

Nutwood UK 2007, 500 reports and anecdotes concerning electromagnetic interference (EMI), collected and edited by Keith Armstrong. Buy from [www.emcstandards.co.uk/books4](http://www.emcstandards.co.uk/books4). Now published as 'EMI Stories' at [www.emcstandards.co.uk/emi-stories](http://www.emcstandards.co.uk/emi-stories), where there are currently 873 of them.

#### ***EMC for Systems and Installations***

By Tim Williams and Keith Armstrong, Newnes, 2000, ISBN: 0-7506-4167-3, [www.bh.com/newnes](http://www.bh.com/newnes), RS Components part number: 377-6463, also available from [www.emcstandards.co.uk/books4](http://www.emcstandards.co.uk/books4).

Keith has written and presented a great many papers for a wide range of symposia, conferences, colloquia, and seminars worldwide, including ERA, IEE, IET, Asia-Pacific EMC, Euro-EMC, and IEEE EMC Society and IEEE Product Safety Engineering Society events. Too many to list here, please ask for further details.

He has also published a great many articles on EMC for publication in professional journals and trade magazines worldwide, including the following five annual series for the EMC Compliance Journal (now available from [www.emcstandards.co.uk](http://www.emcstandards.co.uk)):

- "EMC design of Switching Power Converters" (14 parts, 2011-2013)
- "Designing for EMC" (6 parts 2006-8)
- "Advanced PCB Design for EMC" (8 parts, 2004-5)
- "EMC Testing" (7 parts, 2001-2)
- "EMC for Systems and Installations" (6 parts, 2000)

Keith has written 17 informative booklets on electromagnetic phenomena, what they are, what causes them, how they cause interference, and how to test for them using IEC and EN standard methods, plus another 5 booklets on EMC issues in systems and installations, for example: Power Quality, Good EMC Engineering Practices, Variable-Speed Drives, etc. Free downloads, from [www.emcstandards.co.uk](http://www.emcstandards.co.uk).

Please visit [www.cherryclough.com](http://www.cherryclough.com) or [www.emcstandards.co.uk](http://www.emcstandards.co.uk) for more information.